



November 9, 1982

MTF Test of Proposed Low-Beta Cooling Procedure

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At the request of George Mulholland a comparison was made of results using two cooling procedures for a dipole magnet. Although the final application involves quadrupole magnets, a dipole was selected for the test because it provides a better approximation to the length of the magnet string involved. Figure 1 shows the portion of valving used in cooling a magnet at MTF.

To/from other test stands

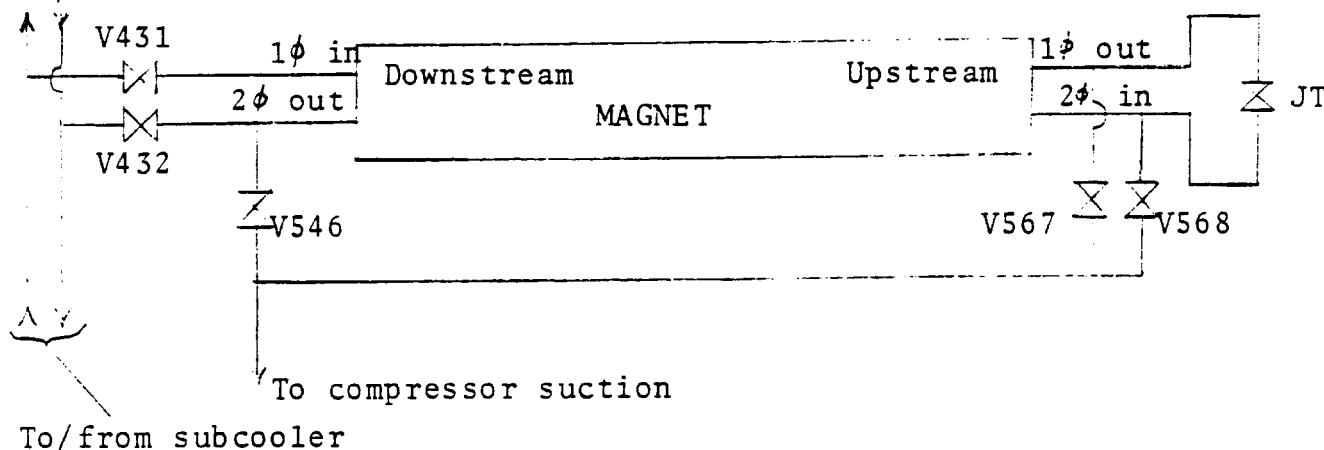


Figure 1

During a standard cooldown V567, V568, and the JT valve are open; other valves are closed. Then V431 is opened to begin the cooldown. When the 1 ϕ out flow reaches LHe temperature, V546 is opened to complete the cooling of the 2 ϕ passages of the magnet and V567 and V568 are closed. When all 4 flows (1 ϕ in, 1 ϕ out, 2 ϕ in, 2 ϕ out) are at LHe temperature V431 is closed and V432 is opened to cool the transfer line between V432 and the magnet. Then V431 is re-opened and V546 is closed. At this point only V431, V432, and the JT valve are open; the JT is set to establish proper pressure, flow, and temperature distributions. The total time for this cooldown procedure is typically 4½ hours.

The proposed low-beta cooldown procedure begins with only the JT valve and V546 open. Then V431 is opened to begin the cooldown. When all 4 flows (1 ϕ in, 1 ϕ out, 2 ϕ in, 2 ϕ out) are at LHe temperature V431 is closed and V432 is opened to cool the transfer line. Then V432 is closed until it is barely cracked, V546 is closed, and V431 is opened to establish a normal flow path. At this point only V431, V432, and the JT valve are open. The JT valve is left wide open and V432 is used to control the flow through the magnet. The total time for this cooldown procedure on magnet TB0381 (test stand 5) was 12½ hours.

The extra step of cooling the 2 ϕ transfer line is needed at MTF to avoid the disruption of cooling to other magnets being tested. This step should not be needed for the low-beta cooldown; however, it takes less than 10 minutes and does not significantly affect our cooldown times.

With the standard cooldown procedure, warm gas from the magnet returns to suction without passing back through the magnet. With the modified cooldown procedure, warm gas from the magnet 1 ϕ passes back through the magnet 2 ϕ and heat exchanges with the magnet 1 ϕ heating the "1 ϕ " liquid/gas. This results in the longer cooldown time using the modified cooldown procedure. The mean indicated 1 ϕ in transfer line flow (from a venturi gauge in the transfer line) was between 6 and 7 gram/sec helium for both cooldown procedures. The cooldown parameters for the two procedures are summarized in Table 1 below.

Table 1

| | Standard cooldown | Low-beta cooldown |
|--------------------------------|-------------------|-------------------|
| 1 ϕ LHe input flow | 6-7 g/sec | 6-7 g/sec |
| 1 ϕ LHe input pressure | 10 psig | 10 psig |
| 1 ϕ LHe input temperature | 4.65 K | 4.65 K |
| LN2 shield input flow | 300 SCFH | 300 SCFH |
| Warm bore in place | Yes | Yes |
| LN2 in warm bore | No | Yes |
| Time for cooldown | 4½ hours | 12¼ hours |

It should be noted that the inside of the warm bore is normally filled with LN2 during quench testing to more nearly duplicate tunnel conditions (under which the magnet bore is at LHe temperature). The warm bore consists of a double walled "tube" with superinsulation and vacuum between the two walls. This permits measurement instrumentation to be inserted into the magnet bore with the bore at LHe temperature. The outer wall of the warm bore is in thermal communication with the magnet bore tube. The inner wall of the warm bore is either at approximately room temperature or at LN2 temperature depending upon whether the warm bore is open or has LN2 in it. The effect of the warm bore on quench performance is small. With 10(-4) torr warm bore vacuum, quench currents with and without LN2 in the warm bore differ by less than 50 amp. With poor warm bore vacuum, quench currents differ by as much as 300 amp. Normal warm bore vacuum is better than 10(-5) torr. The warm bore has negligible effect on cooldown times.

A comparison of quench performance was made using the MTF program "Cycle" for the two types of cooling. Cycle ramps the magnet at a ramp rate of about 200 amp/sec to a target flattop current, holds the flattop current for 20 seconds, and then ramps the magnet back down at the same rate. The minimum current between ramps is 400 amps. A requirement for the test to be considered valid is that 8 ramps be completed at the initial target current without a quench. After the 8 ramps have been completed, the target current is incremented by 50 amps. The program continues incrementing by 50 amps. every second ramp until a quench occurs. For standard cooling, Cycle was run under only one set of cooling conditions. For low-beta type cooling, Cycle was run with three different LHe flow rates. The results are summarized in Tables 2a and 2b.

Table 2a. Cycle test with standard cooling

Cooling parameters:

| | 1 ϕ in | 1 ϕ out | 2 ϕ in | 2 ϕ out |
|-------------------------|-------------|--------------|-------------|--------------|
| Press. (psig): | 9.20 | 9.20 | 4.30 | 4.10 |
| VPT (psig): | 5.80 | 7.10 | 4.00 | 4.00 |
| Subcooling (psi): | 3.40 | 2.10 | 0.30 | 0.10 |
| Temperature (K): | 4.59 | 4.66 | 4.48 | 4.48 |
| 1 ϕ flow (g/sec): | 23.1 | | | |
| Lead flow (SCFH air): | 95 | | | |
| LN2 shield flow (SCFH): | 300 | | | |
| LN2 in warm bore: | Yes | | | |

Cycle results:

| | | | |
|---|------|------|------|
| Target current (amp): | 4335 | 4386 | 4436 |
| Ramp rate (amp/sec): | 201 | 201 | 201 |
| Ramps completed: | 8 | 2 | 0 |
| Current at which quench occurred (amp): | --- | --- | 4436 |
| Time flattop reached after start of ramp (sec): | --- | --- | 20.2 |
| Time quench occurred after start of ramp (sec): | --- | --- | 25.3 |

Table 2b. Cycle test with low-beta type cooling

Set 1: 20 g/sec flow

Cooling parameters:

| | 1 ϕ in | 1 ϕ out | 2 ϕ in | 2 ϕ out |
|-------------------------|-------------|--------------|-------------|--------------|
| Press. (psig): | 9.10 | 9.50 | 9.50 | 9.10 |
| VPT (psig): | 6.70 | 9.00 | 9.00 | 9.40 |
| Subcooling (psi): | 2.40 | 0.50 | 0.50 | -0.30 |
| Temperature (K): | 4.64 | 4.76 | 4.76 | 4.78 |
| 1 ϕ flow (g/sec): | 19.7 | | | |
| Lead flow (SCFH air): | 95 | | | |
| LN2 shield flow (SCFH): | 300 | | | |
| LN2 in warm bore: | Yes | | | |

Cycle results:

| | | | |
|---|------|------|------|
| Target current (amp): | 4136 | 4156 | 4175 |
| Ramp rate (amp/sec): | 201 | 201 | 202 |
| Ramps completed: | 8 | 2 | 0 |
| Current at which quench occurred (amp): | --- | --- | 4176 |
| Time flattop reached after start of ramp (sec): | --- | --- | 18.9 |
| Time quench occurred after start of ramp (sec): | --- | --- | 19.8 |

Table 2b. (Continued)

Set 2: 25 g/sec flow

Cooling parameters:

| | 1 ϕ in | 1 ϕ out | 2 ϕ in | 2 ϕ out |
|-------------------------|-------------|--------------|-------------|--------------|
| Press. (psig): | 8.90 | 9.30 | 9.20 | 8.80 |
| VPT (psig): | 5.90 | 8.60 | 8.60 | 9.00 |
| Subcooling (psi): | 3.00 | 0.70 | 0.60 | -0.20 |
| Temperature (K): | 4.59 | 4.74 | 4.74 | 4.76 |
| 1 ϕ flow (g/sec): | 25.1 | | | |
| Lead flow (SCFH air): | 90 | | | |
| LN2 shield flow (SCFH): | 300 | | | |
| LN2 in warm bore: | Yes | | | |

Cycle results:

| | | | | | |
|---|------|------|------|------|-----|
| Target current (amp): | 4136 | 4176 | 4196 | 4217 | 451 |
| Ramp rate (amp/sec): | 201 | 201 | 202 | 202 | |
| Ramps completed: | 8 | 2 | 2 | 2 | |
| Current at which quench occurred (amp): | --- | --- | --- | --- | |
| Time flattop reached after start of ramp (sec): | --- | --- | --- | --- | |
| Time quench occurred after start of ramp (sec): | --- | --- | --- | --- | |
| Target current (amp): | 4237 | | | | |
| Ramp rate (amp/sec): | 202 | | | | |
| Ramps completed: | 0 | | | | |
| Current at which quench occurred (amp): | 4237 | | | | |
| Time flattop reached after start of ramp (sec): | 19.2 | | | | |
| Time quench occurred after start of ramp (sec): | 29.3 | | | | |

Table 2b. (Continued)

Set 3: 29 g/sec flow

Cooling parameters:

| | 1 ϕ in | 1 ϕ out | 2 ϕ in | 2 ϕ out |
|-------------------------|-------------|--------------|-------------|--------------|
| Press. (psig): | 9.80 | 10.20 | 10.00 | 9.80 |
| VPT (psig): | 6.70 | 8.90 | 9.00 | 9.10 |
| Subcooling (psi): | 3.10 | 1.30 | 1.00 | 0.70 |
| Temperature (K): | 4.64 | 4.76 | 4.76 | 4.77 |
| 1 ϕ flow (g/sec): | 29.0 | | | |
| Lead flow (SCFH air): | 95 | | | |
| LN2 shield flow (SCFH): | 300 | | | |
| LN2 in warm bore: | Yes | | | |

Cycle results:

| | | | | | |
|---|------|------|------|------|------|
| Target current (amp): | 4134 | 4155 | 4175 | 4194 | 4216 |
| Ramp rate (amp/sec): | 201 | 201 | 202 | 201 | 201 |
| Ramps completed: | 8 | 2 | 2 | 2 | 2 |
| Current at which quench occurred (amp): | --- | --- | --- | --- | --- |
| Time flattop reached after start of ramp (sec): | --- | --- | --- | --- | --- |
| Time quench occurred after start of ramp (sec): | --- | --- | --- | --- | --- |

| | | |
|---|------|------|
| Target current (amp): | 4236 | 4256 |
| Ramp rate (amp/sec): | 201 | 202 |
| Ramps completed: | 2 | .0 |
| Current at which quench occurred (amp): | --- | 4255 |
| Time flattop reached after start of ramp (sec): | --- | 19.3 |
| Time quench occurred after start of ramp (sec): | --- | 28.5 |

Table 2. (Continued)

Notes:

- 1) Pressure gauges are accurate to about 0.25 psi.
- 2) VPT pressure gauges are accurate to about 0.15 psi.
- 3) Lead flow is in SCFH air equivalent for each of 2 leads. To obtain flow in liter/hour of LHe multiply by 0.109.
- 4) The calibration used for venturi flowmeters is that a differential pressure Delta P (inches water) is related to flow F (gram/sec LHe) by:
$$F = 7.5 (\text{Delta } P)^{\frac{1}{2}}.$$
- 5) The ramp rate reported is the average between 10% and 90% points of the ramp.
- 6) The current between ramps is typically 410 amp.
- 7) Tests with standard cooling used the standard increment of 50 amp. between currents.
- 8) For tests with low-beta type cooling, the increment was reduced to 20 amp. for better resolution of quench current.

The dependence of Cycle quench current on 1ϕ flow, 1ϕ out sub-cooling, and the product of flow and sub-cooling is shown in Figures 2a, 2b, and 2c. It should be noted that for a given cryogenic installation, *flow and sub-cooling are coupled, in general*. These plots are made from Table 2b. Since input and output 1ϕ temperatures are comparable for each of the three flow rates, quench currents should require minimal correction for temperatures and no corrections have been made in plotting the figures.

Aside from temperature, the dominant cooling parameter affecting Cycle current is the 1ϕ flow rate. This can be seen by comparing Cycle results with low-beta type cooling with the Cycle result with standard cooling. The flow rate with standard cooling was 23.1 g/sec. For this flow rate, Figure 2a predicts a Cycle current of about 4213 amp.

For Fermilab superconductor cable, the dependence of quench current on temperature is approximately given by:

$$\frac{\Delta I}{I} = -2.3 \frac{\Delta T}{T}.$$

For low-beta cooling, $I = 4213$, $T = 4.75\text{K}$. For standard cooling, $T = 4.66\text{K}$. Then:

$$I = -2.3 \left(\frac{-0.09}{4.75} \right) (4213) = 184 \text{ amp.}$$

So the predicted standard cooling quench current would be

$$4213 + 184 = 4397 \text{ amp.}$$

The measured quench current was 4436 amp. which agrees well with the prediction given the 50 amp. granularity of the Cycle test with standard cooling and the 20 amp. granularity with low-beta type cooling.

This result is consistent with the MTF view that provided sub-cooling exceeds some threshold (canonically taken to be about 0.5 psi at MTF), quench results are, to first order, independent of sub-cooling.

Figure 2a. Cycle quench current versus flow with
low-beta type cooling

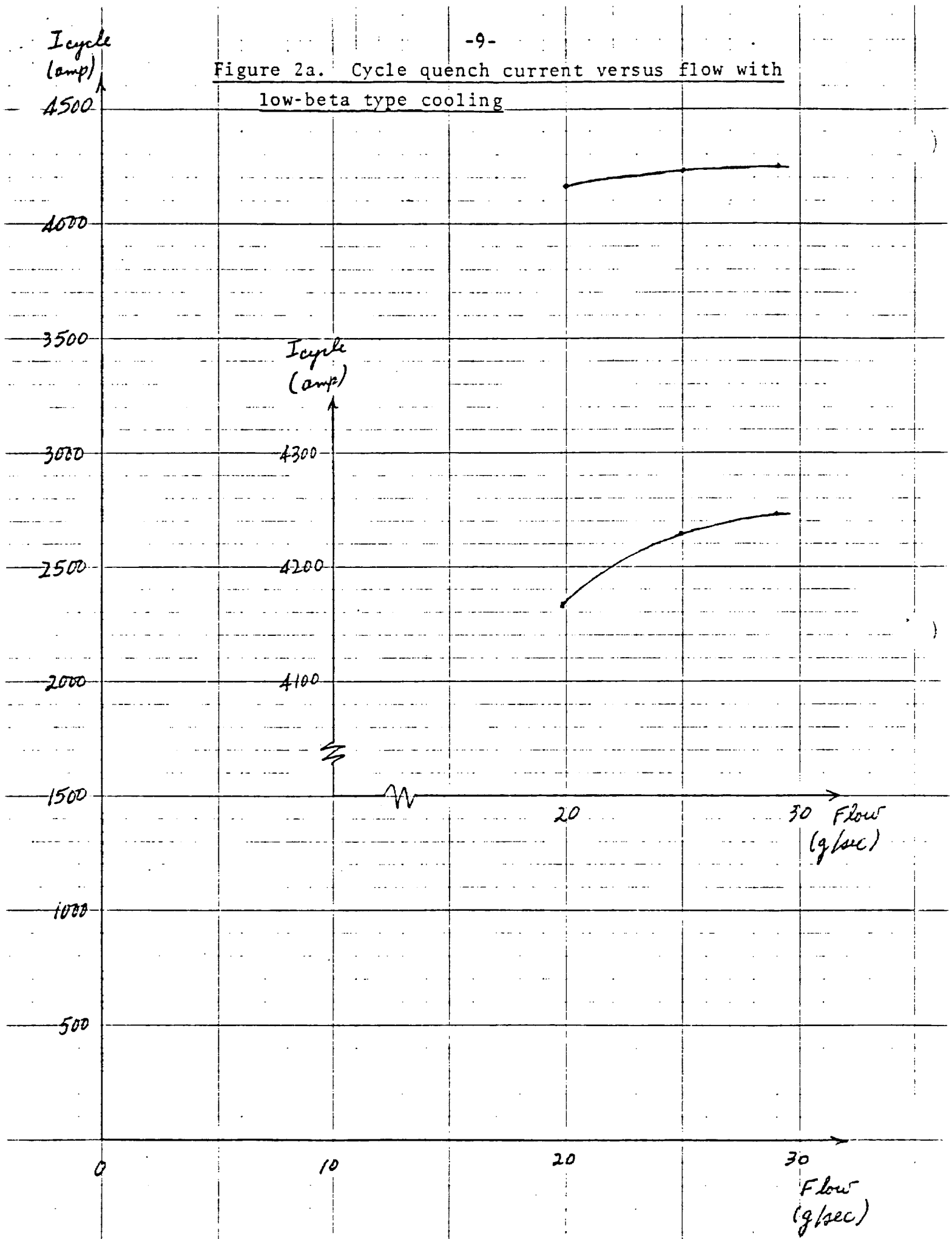


Figure 2b. Cycle quench current versus sub-cooling
with low-beta type cooling

I_{cycle}
(amp)

I_{cycle}
(amp)

1ϕ out
subcooling
(psi)

1ϕ out
subcooling
(psi)

4500
4000
3500
3000
2500
2000
1500
1000
500
0

4300
4200
4100

0

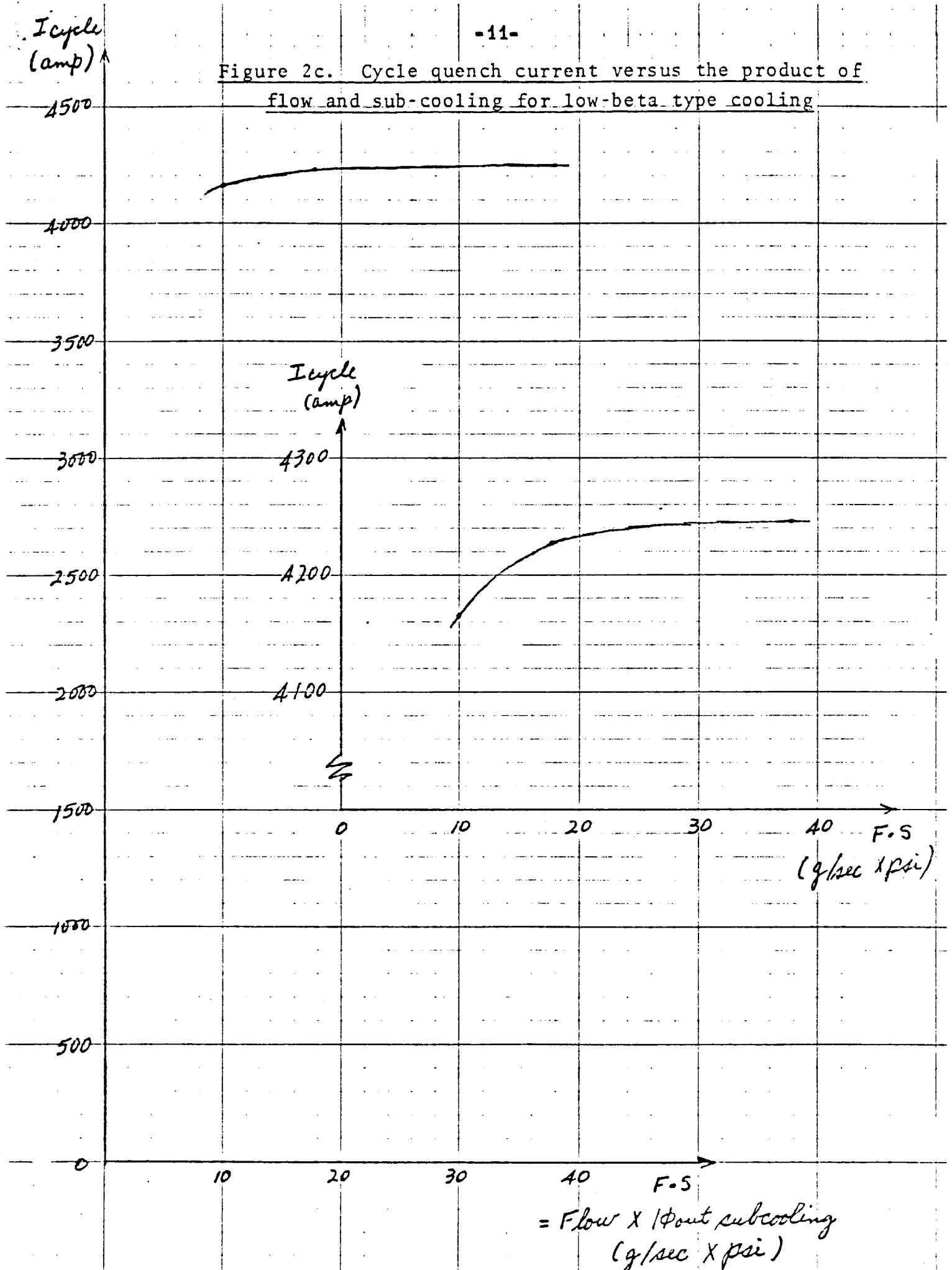
1

2

1

2

Figure 2c. Cycle quench current versus the product of flow and sub-cooling for low-beta type cooling



Three sets of measurements were taken in an effort to see the effect of ramp rate on cooling conditions for low-beta type cooling. The first set of cooling conditions was recorded with zero magnet current. The remaining two sets were recorded while ramping to a nominal flattop current of 4000 amp. with a 20 second flattop, a nominal 400 amp. minimum current, and two seconds between ramps. For each set of conditions, we waited until an equilibrium cooling appeared to be reached. The results are shown in Table 3.

The ramping heat load can be predicted from MTF AC Loss data. Figure 3 shows AC Loss per ramp cycle as a function of flattop current and ramp rate. The data in the figure are raw: no corrections have been applied. Figure 3a shows that loss is approximately linear with flattop current. Figure 3b shows that loss is approximately independent of ramp rate. From Figure 3a, loss/ramp cycle is about 520 joules for a flattop current of 4000 amp. The loss for a ramp from 400 amp. to 4000 amp. should be $0.9 (520)$ joules = 468 joules. For a 200 amp/sec ramp rate, a 20 second flattop, and 2 seconds between ramps, a ramp cycle should take 58 seconds. Then the AC Loss heat load should be $468/58 = 8.1$ watts. For a 100 amp/sec ramp rate, the corresponding number is 5.0 watts. Figure 4 shows the predicted AC Loss heat load as a function of ramp rate for ramps of the type used in the measurements. It is believed that MTF AC Loss data may be systematically high by as much as 15%.

The data in Table 3 are inconsistent with this picture if one assumes 100% liquid in the 1ϕ and 2ϕ ; the 1ϕ heat load would be too high and the 2ϕ heat load too low. I conclude that the 2ϕ was not filled with 100% liquid and that the 1ϕ probably was not either. I have requested that the measurement be repeated. If it were repeated the following changes should be made:

- 1) The measurement should be done on test stand 1. I believe that this stand has substantially better cooling properties than other stands.
- 2) The flattop time should be reduced to near zero to maximize the effect of the AC Loss heat load.
- 3) The time between ramps should be reduced to near zero for the same reason.
- 4) Cooling of other stands should be suspended to maximize the liquid content of 1ϕ delivered to test stand 1.
- 5) Each VPT and pressure gauge should be calibrated immediately before the measurement. If possible, higher quality gauges should be installed.
- 6) The measurements should be made over a greater range of ramp rates.

W. E. Cooper

Table 3. Ramp rate dependence of temperatures for low-beta type cooling

| | 1 ϕ in | 1 ϕ out | 2 ϕ in | 2 ϕ out |
|------------------------------|-------------|--------------|-------------|--------------|
| Set 1: Zero current | | | | |
| Pressure (psig): | 9.50 | 9.65 | 9.55 | 9.55 |
| VPT (psig): | 6.30 | 9.05 | 9.35 | 9.45 |
| Subcooling (psi): | 3.20 | 0.60 | 0.20 | 0.10 |
| Temperature (K): | 4.62 | 4.76 | 4.78 | 4.79 |
| 1 ϕ flow (g/sec): | 20.1 | | | |
| Set 2: 100 amp/sec ramp rate | | | | |
| Pressure (psig): | 9.50 | 9.75 | 9.60 | 9.60 |
| VPT (psig): | 6.50 | 9.30 | 9.40 | 9.45 |
| Subcooling (psi): | 3.00 | 0.45 | 0.20 | 0.15 |
| Temperature (K): | 4.63 | 4.78 | 4.78 | 4.79 |
| 1 ϕ flow (g/sec): | 19.5 | | | |
| Set 3: 200 amp/sec ramp rate | | | | |
| Pressure (psig): | 9.40 | 9.80 | 9.50 | 9.55 |
| VPT (psig): | 6.35 | 9.30 | 9.45 | 9.50 |
| Subcooling (psi): | 3.05 | 0.50 | 0.05 | 0.05 |
| Temperature (K): | 4.62 | 4.78 | 4.79 | 4.79 |
| 1 ϕ flow (g/sec): | 19.9 | | | |

Notes:

- 1) Lead flow = 95 SCFH air equivalent.
- 2) LN2 shield flow = 300 SCFH.
- 3) LN2 present in warm bore.
- 4) Accuracy of pressure gauges is about 0.25 psi.
- 5) Accuracy of VPT pressure gauges is about 0.15 psi.

Figure 3a. AC Loss per ramp cycle versus flattop current *

SECRET

| | | |
|--------|------|----|
| 1-500K | ID = | 40 |
|--------|------|----|

DATE 82/10/11

NO = 14

STANLEY
101
20
00

[illegible]

40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300 310 320 330 340 350 360 370 380 390 400 410 420 430 440 450 460 470 480 490 500 510 520 530 540 550 560 570 580 590 600 610 620 630 640 650 660 670 680 690 700 710 720 730 740 750 760 770 780 790 800 810 820 830 840 850 860 870 880 890 900 910 920 930 940 950 960 970 980 990 1000 1010 1020 1030 1040 1050 1060 1070 1080 1090 1100 1110 1120 1130 1140 1150 1160 1170 1180 1190 1200 1210 1220 1230 1240 1250 1260 1270 1280 1290 1300 1310 1320 1330 1340 1350 1360 1370 1380 1390 1400 1410 1420 1430 1440 1450 1460 1470 1480 1490 1500 1510 1520 1530 1540 1550 1560 1570 1580 1590 1600 1610 1620 1630 1640 1650 1660 1670 1680 1690 1700 1710 1720 1730 1740 1750 1760 1770 1780 1790 1800 1810 1820 1830 1840 1850 1860 1870 1880 1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010 2020 2030 2040 2050 2060 2070 2080 2090 2100 2110 2120 2130 2140 2150 2160 2170 2180 2190 2200 2210 2220 2230 2240 2250 2260 2270 2280 2290 2300 2310 2320 2330 2340 2350 2360 2370 2380 2390 2400 2410 2420 2430 2440 2450 2460 2470 2480 2490 2500 2510 2520 2530 2540 2550 2560 2570 2580 2590 2600 2610 2620 2630 2640 2650 2660 2670 2680 2690 2700 2710 2720 2730 2740 2750 2760 2770 2780 2790 2800 2810 2820 2830 2840 2850 2860 2870 2880 2890 2900 2910 2920 2930 2940 2950 2960 2970 2980 2990 3000 3010 3020 3030 3040 3050 3060 3070 3080 3090 3100 3110 3120 3130 3140 3150 3160 3170 3180 3190 3200 3210 3220 3230 3240 3250 3260 3270 3280 3290 3300 3310 3320 3330 3340 3350 3360 3370 3380 3390 3400 3410 3420 3430 3440 3450 3460 3470 3480 3490 3500 3510 3520 3530 3540 3550 3560 3570 3580 3590 3600 3610 3620 3630 3640 3650 3660 3670 3680 3690 3700 3710 3720 3730 3740 3750 3760 3770 3780 3790 3800 3810 3820 3830 3840 3850 3860 3870 3880 3890 3900 3910 3920 3930 3940 3950 3960 3970 3980 3990 4000 4010 4020 4030 4040 4050 4060 4070 4080 4090 4100 4110 4120 4130 4140 4150 4160 4170 4180 4190 4200 4210 4220 4230 4240 4250 4260 4270 4280 4290 4300 4310 4320 4330 4340 4350 4360 4370 4380 4390 4400 4410 4420 4430 4440 4450 4460 4470 4480 4490 4500 4510 4520 4530 4540 4550 4560 4570 4580 4590 4600 4610 4620 4630 4640 4650 4660 4670 4680 4690 4700 4710 4720 4730 4740 4750 4760 4770 4780 4790 4800 4810 4820 4830 4840 4850 4860 4870 4880 4890 4900 4910 4920 4930 4940 4950 4960 4970 4980 4990 5000 5010 5020 5030 5040 5050 5060 5070 5080 5090 5100 5110 5120 5130 5140 5150 5160 5170 5180 5190 5200 5210 5220 5230 5240 5250 5260 5270 5280 5290 5300 5310 5320 5330 5340 5350 5360 5370 5380 5390 5400 5410 5420 5430 5440 5450 5460 5470 5480 5490 5500 5510 5520 5530 5540 5550 5560 5570 5580 5590 5600 5610 5620 5630 5640 5650 5660 5670 5680 5690 5700 5710 5720 5730 5740 5750 5760 5770 5780 5790 5800 5810 5820 5830 5840 5850 5860 5870 5880 5890 5900 5910 5920 5930 5940 5950 5960 5970 5980 5990 6000 6010 6020 6030 6040 6050 6060 6070 6080 6090 6100 6110 6120 6130 6140 6150 6160 6170 6180 6190 6200 6210 6220 6230 6240 6250 6260 6270 6280 6290 6300 6310 6320 6330 6340 6350 6360 6370 6380 6390 6400 6410 6420 6430 6440 6450 6460 6470 6480 6490 6500 6510 6520 6530 6540 6550 6560 6570 6580 6590 6600 6610 6620 6630 6640 6650 6660 6670 6680 6690 6700 6710 6720 6730 6740 6750 6760 6770 6780 6790 6800 6810 6820 6830 6840 6850 6860 6870 6880 6890 6900 6910 6920 6930 6940 6950 6960 6970 6980 6990 7000 7010 7020 7030 7040 7050 7060 7070 7080 7090 7100 7110 7120 7130 7140 7150 7160 7170 7180 7190 7200 7210 7220 7230 7240 7250 7260 7270 7280 7290 7300 7310 7320 7330 7340 7350 7360 7370 7380 7390 7400 7410 7420 7430 7440 7450 7460 7470 7480 7490 7500 7510 7520 7530 7540 7550 7560 7570 7580 7590 7600 7610 7620 7630 7640 7650 7660 7670 7680 7690 7700 7710 7720 7730 7740 7750 7760 7770 7780 7790 7800 7810 7820 7830 7840 7850 7860 7870 7880 7890 7900 7910 7920 7930 7940 7950 7960 7970 7980 7990 8000 8010 8020 8030 8040 8050 8060 8070 8080 8090 8100 8110 8120 8130 8140 8150 8160 8170 8180 8190 8200 8210 8220 8230 8240 8250 8260 8270 8280 8290 8300 8310 8320 8330 8340 8350 8360 8370 8380 8390 8400 8410 842

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* * * * *
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SATURATION AT= 255
SCALE .+.2.3. . . A.B.
STEP = 1 * MINIMUM=0

```

PLOT STATISTICS

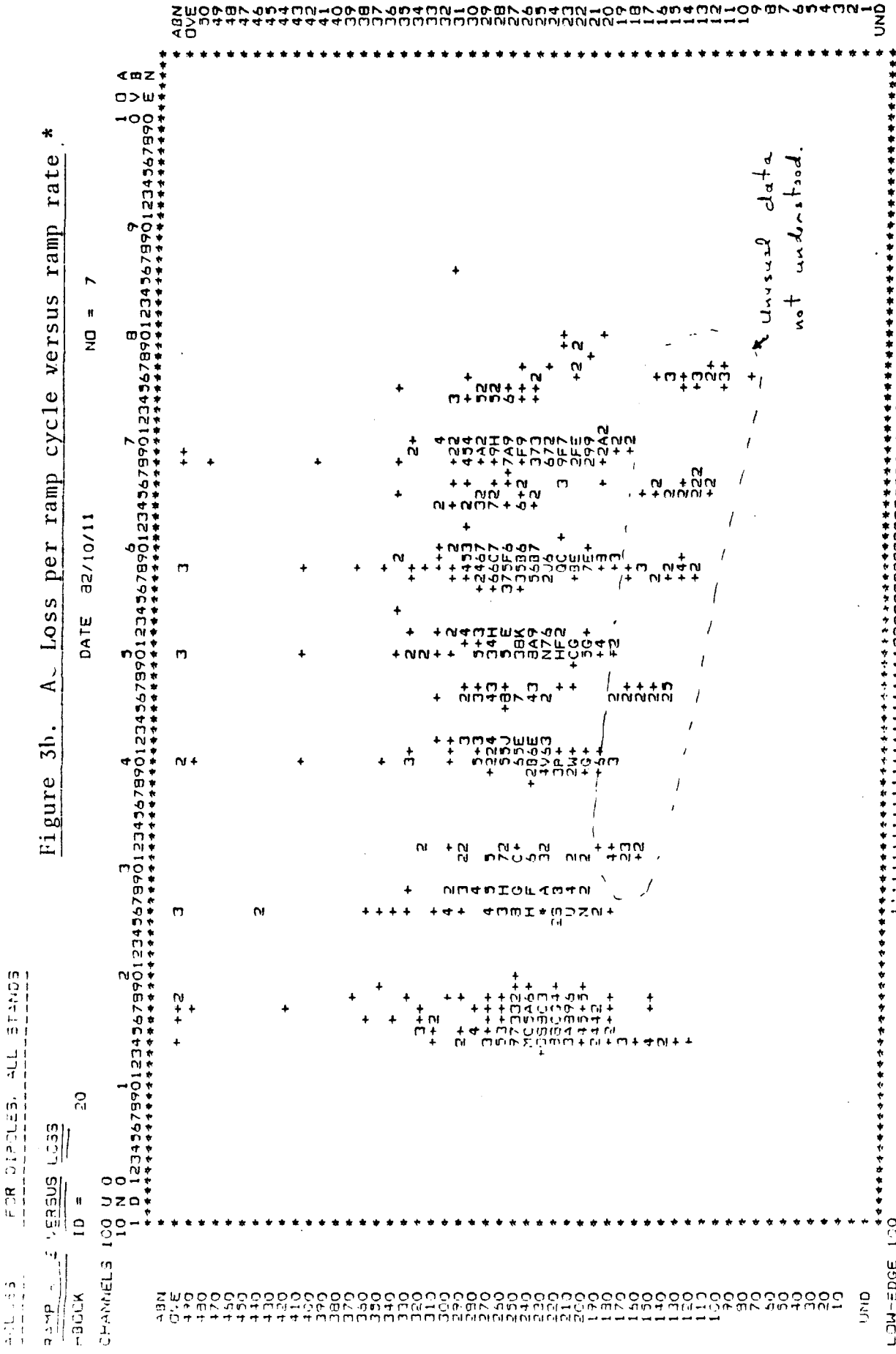
17-03

Flat top
(Amp)
by "Jay" Schmid
→

@ Ramp RATE 180 A/sec to 240 A/sec

* Plot supplied by "Jay" Schmidt.

Figure 3b. A Loss per ramp cycle versus ramp rate *



ENTRIES = 1920
SATURATION AT = 53
SCALE = 1, 2, 3, ... A, B, C
STEP = 1 * MINIMUM=0

PLAT

STATISTICS

1902

RAMP RATE →
(AMP/SEC)

@ Flat top 1940 A & 2020 A

* Plot supplied by "Jay" Schmidt.

Figure 4. AC Loss heat load as a function of ramp rate

Heat load
(Watts)

Minimum current = 400 amp.
Flat top current = 4000 amp.
Flat top time = 20 seconds.
Time between ramps = 2 seconds.

14

12

10

8

6

4

2

0

100

200

300

400

500

Ramp rate
(amp/sec)

